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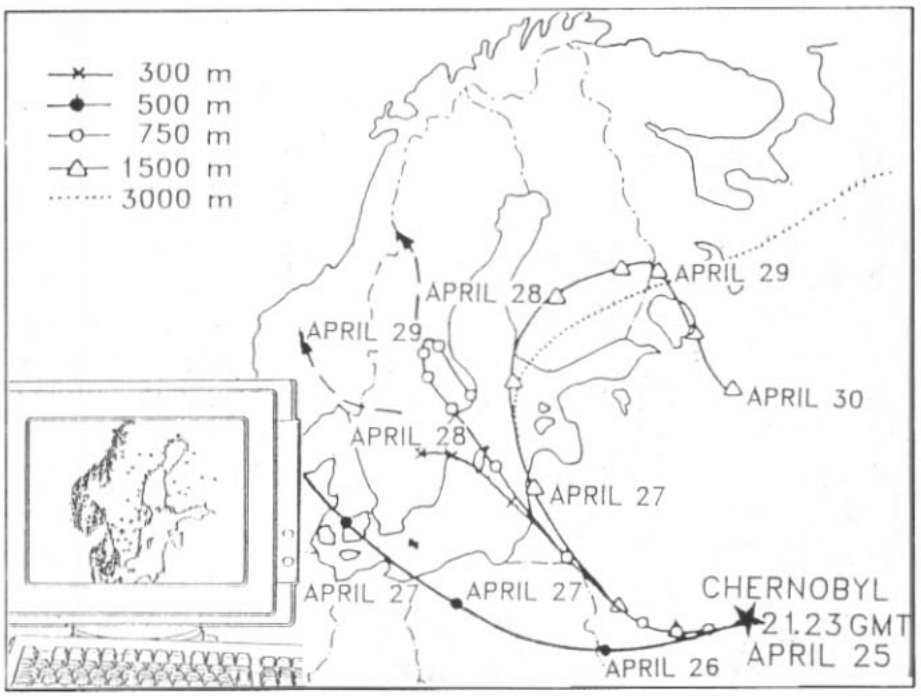
ENVIRONMENTAL RADIOACTIVITY MEASUREMENTS



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Nordic
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THE NORDIC CHERNOBYL DATA BASE

ENVIRONMENTAL RADIOACTIVITY MEASUREMENTS

Final Report of the NKA Project AKT 242

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ABSTRACT.

The NORDIC CHERNOBYL DATA BASE (NCDB) is established for scientific purposes. The aim is to collect valid data on radiation and radioactivity resulting from measurements made in the Nordic countries particularly after the Chernobyl accident.
All information is stored in the so called C_base data system, which can handle input from a variety of sources, including multiple information on each sample. The system permits output to various other computer programs for further data treatment.
The data base can be used from personal computers as well as from VAX-computers.
Data can be displayed in time- or geographical scales and they can be arranged so as to fit different systems for statistical analysis.

Keywords: Accidents, calibration standards, Cesium, Chernobylsk-4 reactor, computer calculations, data acquisition systems, data processing, Denmark, Finland, Iodine, Norway, radiation monitoring, radioactivity, Sweden.

SUMMARY

Short time after the Chernobyl accident on April 26 1986, a sub-committee under the Nordic Liaison Committee for Atomic Energy decided to initiate the creation of a joint data base for the many measurements of radiation and radioactivity that were registered in laboratories in the Nordic countries.

The purpose was to facilitate future research through collection in a single place of so many as possible of the measurements from the Nordic countries.

Cooperation was also intended with other organizations with similar tasks, as e.g. The EEC "REM-bank" in Ispra, so that exchange of data could be arranged.

The project management was placed at Risø, and a working group was formed of specialists from the four participating Nordic countries.

Four national representatives act as contact persons and have responsibility for the gathering of the national data. They have competence to classify the in-going data with respect to quality.

A previously established Nordic fallout database (NFD), containing measurements of Sr-90 and Cs-137 fallout data collected since the late 1950ies, is transferred into the new data base.

None of the data base systems that were available in 1986 proved to be well suited for the easy and fast handling of large and complex amounts of data. It was therefore decided to develop a special system based on Risø's earlier experience.

The new data base is designed to permit fast and flexible input/output of data with a high degree of economy of data storage space. It has capability for selection and treatment of almost all kinds of results and documentary messages

within the environmental field. A flexible system for presentation of variations of every kind in time or place is used so that geographical variations can be described and displayed in the coordinate systems in use in the Nordic countries.
Enlargement of maps of specific areas is also possible.

So far 21 laboratories in the Nordic countries are involved in the data collection. An intercalibration exercise has been performed in order to ascertain the quality of the input to the data base. All laboratories have an acceptable standard of Cesium measurements, but there is a need for continued intercalibration exercises with other radionuclides than Cesium.

The quality of any measurement contained in the data base is classified according to three factors, including the uncertainty of the measurement, the procedure followed during sampling, and the quality of calibration in the laboratory that has delivered the data.

The data base system developed is written in the C programming language. It consists of a binary file system and a number of handling modules. In order to facilitate transfer of data between the different computer systems to be used, additional software and user-interface programs have been developed.

Users in the Nordic countries will receive updated copies of the data base at regular intervals. Parallel versions for PC's and for VAX-machines will be maintained.

Summary in Danish

SAMMENFATNING.

Kort tid efter Chernobyl-ulykken den 26. april 1986 besluttede en komite under Nordisk kontaktorgan for atomenergispørgsmål at tage initiativ til oprettelsen af en fælles database for de mange målinger af radioaktivitet og stråling, som blev registreret i de Nordiske laboratorier.

Formålet var at lette fremtidig forskning gennem samling i en central database af så mange som muligt af disse målinger fra de Nordiske lande.

Det var også hensigten at samarbejde med andre organisationer med tilsvarende opgaver, som f.eks. EF-REM-banken i Ispra, således at udveksling af data kunne arrangeres.

Projektledelsen blev lagt på Risø, og der blev oprettet en arbejdsgruppe af specialister fra de fire deltagende Nordiske lande.

Fire nationale repræsentanter fungerer som kontaktpersoner og har ansvaret for indsamling af de nationale data. De har kompetance til at klassificere de indleverede data med hensyn til kvalitet.

En tidligere etableret Nordisk Fallout Database (NFD), der rummer målinger af Sr-90 og Cs-137 fra atmosfæriske kernevåbensprængninger siden sidst i 1950'erne, er overført til den nye database.

Ingen af de databasesystemer, der var til rådighed i 1986, viste sig at være særligt egnede til nemt og hurtigt at håndtere store og komplekse datamængder. Det blev derfor besluttet at udvikle et særligt system baseret på Risøs tidligere erfaringer.
Den nye database er tilrettelagt med henblik på at data hurtigt og fleksibelt kan håndteres med en høj grad af økonomi i datalagring.

Den har mulighed for udvælgelse og behandling af næsten alle slags resultater og dokumentariske meddelelser inden for miljøområdet.
Et fleksibelt system til præsentation af variationer af enhver art i tid og sted muliggør at geografiske variationer kan beskrives og vises i de forskellige koordinatsystemer, der bruges i Norden.
Forstørrelse af kort over specifikke områder kan også vises.

Hidtil har 21 laboratorier i de Nordiske lande været involveret i dataindsamlingen.

En interkalibreringsøvelse har været afholdt for at undersøge kvaliteten af de data, der skal indføres i databasen.
Alle laboratorier kunne måle Cæsium med tilfredsstillende resultat, men der viser sig at være et behov for fortsatte interkaliberings-øvelser med andre radionuklider end Cæsium.

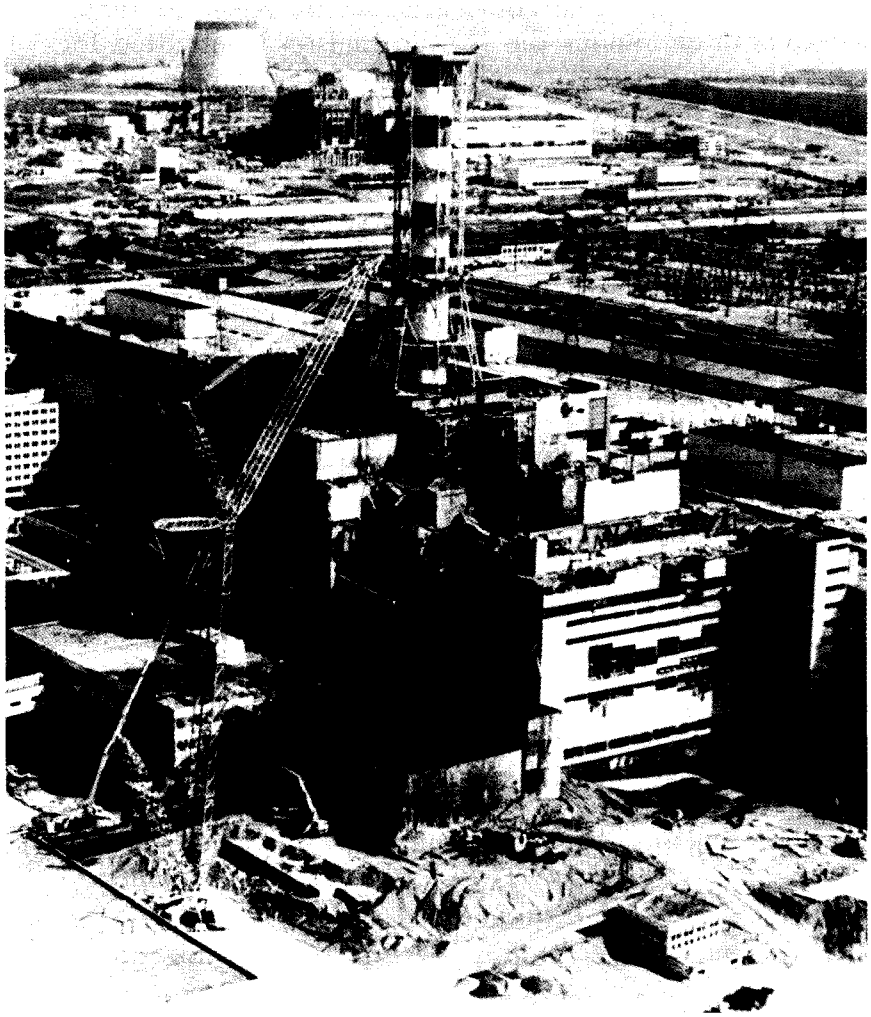
Kvaliteten af de målinger, der indgår i databasen er klassificeret med tre faktorer, der omfatter: Målingens usikkerhed, proceduren der er fulgt under indsamlingen, samt kalibreringskvaliteten hos det laboratorium, som har leveret dataene.

Det databasesystem som er udviklet er skrevet i programmeringssproget C. Det består af et binært fil-system samt et antal håndteringsmoduler.
For at lette overførsel af data mellem de forskellige edb-systemer, der anvendes i de enkelte laboratorier, er der udviklet yderligere software og bruger-interface programmer.

Brugere i de Nordiske lande vil modtage opdaterede kopier af databasen med regelmæssige mellemrum.
Parallelle versioner for PC'ere og VAX-maskiner vil blive vedligeholdt.

List of contents

1. Introduction 2
2. The task 3
3. The background 7
4. Outline of the NCD 8
5. Data quality 10
6. Intercalibration exercise 15
7. Introduction to the C_base data handling system 19
8. Access to the NCDB 19
9. International cooperation 20
10. References 21
11. Working group



Aerial view of the damaged reactor nr. 4
at the Chernobyl Nuclear Power Plant.
(Photo: TASS)

1. INTRODUCTION

One week after the Chernobyl accident on April 26 1986, a sub-committee under the Nordic Liaison Committee for Atomic Energy decided to initiate the creation of a joint data base for measurements of radiation and radioactivity that were performed in Nordic laboratories after the Chernobyl accident.

A pre-project was conducted by the Swedish National Institute of Radiation Protection to evaluate the possibilities for a common Nordic scientific data base, including the data files already established in Sweden.

The final project was established late in 1986 within the Nordic cooperation in nuclear safety (project 242):

NORDIC CHERNOBYL DATA BASE OF VALID, SCIENTIFIC DATA ON RADIATION AND RADIOACTIVITY AFTER THE CHERNOBYL ACCIDENT.

It was further decided, that this project should be coordinated by Risø National Laboratory.
After some contact meetings, a working group consisting of specialists from Finland, Norway, Sweden and Denmark was established with the task of guiding the project.

The Swedish National Institute of Radiation Protection has all the way had the secretariat function of the project.

It was decided to perform an intercalibration exercise among the participating laboratories.

This report describes the development of the data base, its handling systems, its data quality indication system and the results of the intercalibration exercise.

2.THE TASK.

The main aim of the project was to facilitate future scientific work by:

> Collecting in a single place as much as possible of the large amount of information concerning radiation and radioactivity in man and the environment resulting from the investigations in the Nordic countries particularly after the Chernobyl accident.

Further it was the aim to utilize the Nordic Fallout Database, established at Risø in 1980, which contains similar fallout data obtained since the late 1950'ies.

It was also the task to enhance a unified approach to the interpretation of radioactivity measurements, i.e. through intercalibration exercises between the laboratories to be involved.
A final consideration was to facilitate cooperation with international agencies doing similar work, like the EEC REM-bank, situated in Ispra.

3. THE BACKGROUND.

The amount and variety of information about radiation- and radioactivity levels in the Nordic countries is large and the amount is rapidly growing.

Before Chernobyl.

The above-mentioned Nordic Fallout Database (NFD) has the following background:
For more than 20 years, fallout radioactivity in air, precipitation, soil, foodstuffs etc. was measured by different Nordic institutions.

Many of these data were published in various reports and/or in articles in scientific journals. It was difficult to get a general view of the measurements and therefore not easy to use the information contained in these data. Therefore it was decided in 1980 to register Nordic fallout data in a common data base.

The NFD consists of measurements of the long-lived isotopes Cesium-137 and Strontium-90 originating from nuclear weapons tests, sampled in all four Nordic countries. For some typical foodstuffs, annual mean values are stored, For air, precipitation and milk, monthly values are registered. [5].

A program system (STATDATA), available in 1980, was used for data handling. Each fallout measurement is stored as a data set or a so-called record.
Such a record consists of the measurement and 6 parameters characterizing the measurement. [1].

One weakness in the NFD is the difficulties in defining geographical localities, since postal codes were used. Another weakness was the limited number of parameters available for characterizing a measurement.

The NFD contains 14,490 measurements of caesium-137 and strontium-90 from the four Nordic countries.

The scientific value of the NFD is demonstrated by its use as a base for development of prediction models for the movement and accumulation of radionuclides in the environment.
It has also been used for calculation of so-called radioecological sensitivities, defined in [7]. [6].

After Chernobyl.

After the Chernobyl accident, the situation was too complicated to make an efficient use of the above mentioned data system, STATDATA, available only at Risø. Additional types of measurements and much larger amounts of information needed to be stored and handled.

One record to be entered into the data base might be as simple as a measurement of the dose rate at well defined time, location and conditions e.g.

> 0.0804 microSv/h at 1807 on April 27 1986, 1 meter above ground in free air, dry weather, at Risø (UTM coordinates: UB 168 762), instrument: Reuter Stokes high pressure ionization chamber, measured by Health Physics Dept., Risø National Laboratory.

Seen from a data handling viewpoint, the amount of information in this record is relatively small and should be easy to handle.

Another information might be a little more complicated like a gamma ray spectrum of 4000 channels at well defined time, location and conditions.

The amount of information is much larger here, but it can still be easily handled.

If the information concerns the radioactivity content in an environmental sample, then the information record will consist of several so called fields (or parameters) describing:

- type of sample,
- method of sampling (generally a standard method for the type of sample),
- time of sampling,
- geographical location (perhaps height above/below the sea-level),

- physical conditions of the sample (wet, dry, ashed etc.),
- method of treatment in the laboratory in question with reference to previously published reports,
- applied measurement techniques, also with references,
- isotope or other relevant kind of quantity such as relations between amounts of specific isotopes,
- time of measurement,
- unit of the measured value,
- reference time (e.g. calculated isotope value at the time of the Chernobyl accident),
- the estimated accuracy of the value.

From this list it becomes obvious that the data handling system needs to be able to handle a considerable number of variables. It should thus be able to handle all information collected in a detailed and complicated laboratory investigation of a long earth profile sample, including analyses for determination of different isotopic concentrations versus time/depth of the profile with many micro-chemical conditions as essential parameters. References to several publications might also be needed.

4. OUTLINE OF THE NCDB.

An initial search showed, that data base systems existing in 1986 - mainly constructed for administrative purposes - were not well suited for handling the large and complex data amounts in question.
Therefore it was decided to develop a special data base system which would be able to make full use of modern hardware/software and to give:

- a fast and flexible input/output of data
- a high degree of economy of data storage space
- possibility for collection and treatment of almost all kinds of experimental results and documentary messages especially from the environmental field.
- a flexible system for presentation of variations in e.g. time or geographical position of a certain sample type.
  The geographical presentation should be made in suitable coordinate systems covering large regions (Europe/Scandinavia) and also have zoom-in possibilities for presentation of local details (Such as the Gävle-area in Sweden).

It was further decided, that the NCDB should be developed for use on personal computers as well as on VAX-computers.

A technical report has been worked out to describe the system developed for the NCDB [2].
In this report all necessary functions are outlined.
It serves as an Input/Output and Handling guide to the NCDB.

5. DATA QUALITY.

The quality of the data to be included in the NCDB has been a constant concern for the Nordic working group in charge of guiding the project.
A valid measurement of the content in an environmental sample of a certain isotope presumes that the laboratory in question has an intimate knowledge of the calibration of the applied set-up of detector and sample (including the sensitivity of detector versus energy, distance of source, dimensions of source, density etc.).

Intercalibration exercise.

The working group decided at an early stage to perform a Nordic intercalibration exercise.

The intercalibration exercise is described in more detail in section 6 below.

Data classification.

Discussions within the working group led also to a system for classification of the validity of the data to be included in the NCDB.

Three factors have been considered:
- measurement uncertainty
- sampling quality and
- calibration quality.

The measurement uncertainty is coupled to a quality code indicating the relative standard deviation (S.D.).
6 discrete values have been selected: S.D. below 5%, 10%, 20%, 30%, 50%, and unknown.

The sampling quality is indicated by the following 5 letters:

A: Standard procedures have been used for sampling, replicate samples, controlled homogenizing and sub-samples

B: Standard procedure has been used for sampling and control of homogenizing and selection of sample for measurement.

C. Standard procedures for sampling have been used.

D: Non-standard procedures have been used (methods should be described in the referenced publication or in a common text record).

U: unknown procedures.

The calibration quality is indicated by the 3 letters:

I: The laboratory has participated in intercalibrations.

R: Standard reference materials have been used.

U: Unknown.

Where this information is not given, the authority to determine the quality of each input to the NCDB was delegated to the national representatives in the working group.

6. INTERCALIBRATION EXERCISE.

The amount of measurement data after Chernobyl was vast and with a large variation in quality in sampling method, sampling treatment, measurement technique, etc. Therefore it was decided to perform an intercalibration exercise among the participating laboratories.

The exercise included three steps:
- Production of the necessary number of intercalibration samples.
- Distribution to the participating laboratories with subsequent measurements.
- Analysis of the results obtained.

Intercalibration samples.

Two sets of each six samples, containing different, relevant isotopes in differing amounts, were produced for each of the four Nordic countries. The samples were:

1. Dried milk,
2. Lichen, collected in the Härnösand area, northern Sweden,
3. Seaweed, collected close to the Ringhals nuclear power plant,
4. Water sample, synthetic with short lived isotopes added,
5. Low activity, deep layer soil sample, (background sample, 2 m deep clay layer, Risø area),
6. Swedish surface soil from the Gävle area, Sweden.

The lichen samples were produced by the Swedish National Institute for Radiation Protection, Stockholm, all the other by Risø National Laboratory.

All the samples were - after control of their homogeneity - distributed at the end of 1987.

Participants.

In the final analysis, 21 laboratories participated:
3 Danish, 3 Finnish, 4 Norwegian and 11 Swedish:

Risø National Laboratory,
State Radiation Hygiene Institute, Copenhagen,
Dept. of Electrophysics, Technical University of Denmark.

Dept. of Radiochemistry, University of Helsinki,
Finnish Center for Radiation and Nuclear Safety (STUK), (Helsinki),
Dept. of Environmental Hygiene and Toxicology, National Public Health Institute, Kuopio.

Isotope Laboratory, Agricultural University of Norway,
Institute for Energy Technology, Kjeller,
National Institute of Radiation Hygiene, Oslo
Institute for Anorganic Chemistry, Technical University of Norway,

Swedish National Institute for Radiation Protection, (Stockholm),
Ringhals Nuclear Power Plant,
Oskarshamn Nuclear Power Plant,
Forsmark Nuclear Power Plant,
National Defence Research Establishment, Umeå,
National Environment Protection Board, Stockholm,
Institute for radiophysics, Umeå University,
Institute for radiophysics, Sahlgrenska Hospital, Göteborg,

Institute for radiophysics, The Hospital, Lund,
Studsvik,
Swedish University of Agricultural Sciences,
Uppsala

Interest for participation was later expressed by Iceland and the Färoe Islands, and sets of samples have been delivered for their measurements. The results are not yet available.

Intercalibration procedure.

In spring 1988 most of the calibration data were received by the secretary of the working group, and a preliminary analysis was made. Some corrections had to be made, especially with respect to reference date (the date to which the radioactivity amount is back-dated).
A final analysis was made by Risø in spring 1989.

Analysis results.

A detailed, preliminary list of all received measurements (randomly numbered) was then distributed to each laboratory.
Each participant was informed only about the number of his own measurements.
The main conclusion from this intercalibration analysis is:

All Cesium measurements (Cs-134, Cs-137) from the 21 participating laboratories are acceptable.

All background measurements (sample no.5) from the 12 laboratories who gave results on the sample, are acceptable.

With respect to other specific isotopes than radiocesium, the results were not quite so satisfactory.
This shows a need for further intercalibration exercises with radionuclides other than Cesium.

The following, more detailed conclusions could be drawn from the analysis:

1. There was no significant difference between the 21 laboratories with regard to Cs-137 determinations in the 5 samples. The relative Standard Deviation (SD) between the laboratories was 13 %.

2. For Cs-134 the same conclusion was drawn. Here the SD was 15 %.

3. The analysis of variance (anova) for lichen (sample nr. 2) showed that with regard to Cs-137, Cs-134 and Ag-110m the labs did not differ, but the relative SD was 27 %. If one lab of the 15, who participated in this test was omitted, the relative SD between the laboratories dropped to 15 %.

4. In case of dried milk (sample nr. 1) for Cs-137, Cs-134 and K-40, two labs were outliers. If these were omitted, there was no significant difference between the remaining 14 labs with a relative SD of 13 %.

5. For seaweed (sample nr. 3) the following radionuclides were included in the anova: K-40, Mn-54, Co-58, Co-60, Zn-65, Cs-134 and Cs-137.
If four labs were omitted, there was no significant difference between the remaining 13 labs. The relative SD was then 7 %.
If only the 5 labs, which had determined all 7 radionuclides, were considered, the relative SD was 4 %.

6. In Swedish surface soil (sample nr. 6) K-40, Mn-54, Ru-106, Ag-110m, Sb-125, Cs-134 and Cs-137 were included in the anova. If 4 labs are omitted and if K-40 is not included in the anova, there is no significant difference between the remaining 14 labs, and the relative SD becomes 8%.

7. In the water sample (sample nr. 4) Ru-103, Ru-106, Cs-134, Cs-137 and Ce-144 were determined. If 2 labs were omitted, the relative SD became 7 % between the remaining 13 labs.
If the anova was confined to those labs which had analyzed all 6 radionuclides and one lab omitted, the relative SD between the remaining 9 labs became 4 %.

8. The analysis of Deep Danish Soil (sample nr. 5), which should be free of radiocesium, was performed by 12 labs. None of the laboratories found Cs-137 significantly different from zero activity.
This assures that no radiocesium contamination in these laboratories have disturbed the measurements.

7. INTRODUCTION TO THE C_BASE DATA HANDLING SYSTEM.

The software foundation - named the C_base system - of the NCDB is developed at Risø as an improvement of the earlier system: STATDATA that had been available for several years and in use in the Nordic Fallout Database.

The C_base data handling system is designed for use in connection with almost all kinds of measurements, experimental results and documentation within the environmental field.

Common to the NCDB - as to all data handling systems - are concepts such as:

- word: Data storage unit (here 8 bytes),
- key (keyword): a name or a number used for characterizing and searching,
- field: a data storage space containing a key or any other information (here one word),
- record: consisting of a set of fields. Normally the records consist of a fixed number of fields with well defined types and sizes,
- files consisting of a set of records.

Most data base systems are designed for administrative purposes. They use large numbers of files, containing tables of keywords and references. They provide fast access to selected data, but they allow rather little flexibility in the structures, once they are defined.

In order to improve flexibility the C_base system uses a different approach:

Any single item (i.e. a measurement) is stored in a separate record including a specifier field, which describes the number of fields used and the type of their content.

A record may contain anything from:
A single field to
large, fully labeled measurements,
geographical coastlines,
multichannel spectra,
digitized pictures or
large documents.

In order to obtain fast input/output and a high degree of economy in storage space, records are stored in binary files.

In order to facilitate program transfer between different computer systems, the C_base system is written in the C programming language.

A detailed review of the C_base system is given in the above-mentioned technical report [2].

The C_base system consists of:

- A basic binary file system
- a number of modules for handling input/output in text-form
- modules for selection, sorting, plotting, various calculations etc.
- graphical modules for map plotting etc.

To make best use of these, several user-interface programs have been developed:

FILEHANDler - a program to perform all normal data and file operations. It includes a special keyboard input & edit window module and a macro facility. [3].

MAPHANDler - a program to draw maps and show labels and/or values from records according to coordinates in the record. [4].

The programs and data of the NCDB are developed for and stored on different computer installations.
A transfer file format has been developed to move data between the different systems.

The NCDB exists or is planned in the following versions:

PC-version: to be used on any IBM-PC compatible machine. Data and code is interchanged using ordinary diskettes, primarily 3.5" - 720 kbyte and 5.25" - 1.2 Mbyte.

The MAPHANDler may present problems for the graphical part due to the many different types of displays.

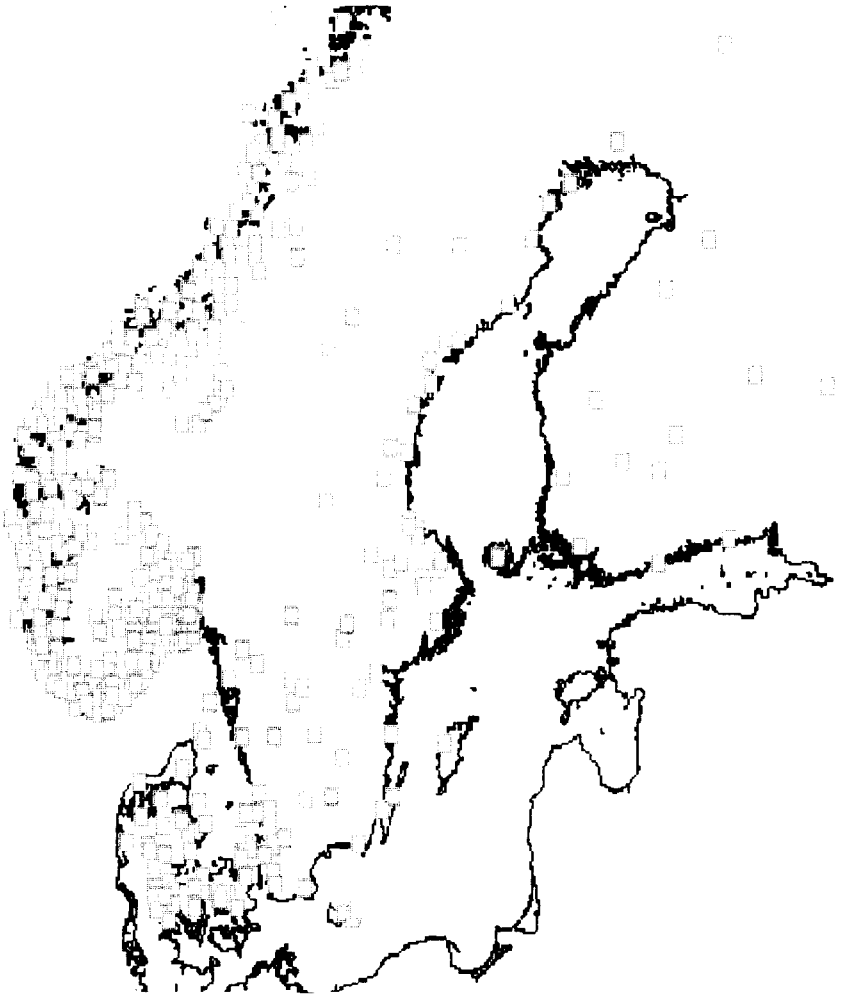
The FILEHANDler uses no graphics.

VAX-version: may be used on any Digital-VAX-machine; data and code are moved using tapes. Access to the machines will be possible through telephone lines or public networks.

UNIX-version: not implemented presently, but implementation on UNIX/386 is foreseen.

It should be stressed that the system developed for the NCDB can be characterized as a versatile tool for handling large and complicated amounts of data. Thus the same system could also be used in areas outside the environmental field.

The following example gives an idea of the illustrative possibilities of the C_base system.



The figure shows the milk sampling locations in Scandinavia in the period May - August 1986.
In Norway each community is shown, while in the other three countries only the few, very large milk sampling centers, each covering several communities, are shown.

In the NCDB emphasis is put on the description of a locality.
All records must contain a location name and a set of location coordinates in the record specifier fields.
In the case of average values of nearby locations, some average coordinates must be given.
8 discrete coordinate codes are available in the NCDB:
One for "Geographical latitude/longitude",
Five for the UTM systems: UTM31 - UTM35,
One for "Riket Net" (Sweden) and
One for "Fingis" (Finland).

8. Access to the NCDB.

The working group of the NCDB has decided to delegate to each national member the responsibility for collecting the national data and presenting output on request.
They will be assisted technically from Risø where the final accumulation into a master copy of the NCDB and subsequent distribution will take place.
It is the intention to keep parallel versions on a VAX-machine and on PC's, from which tapes and diskettes may be copied to other users.
The necessary software will be distributed in the same manner. On-line access to the VAX'es may be provided through the national working group members.

9. International cooperation.

The relations to the REM-bank at Ispra are established and will be updated.
In the layout of the specification tables for the NCDB records, the corresponding layouts in the REM-bank have been considered and taken into account whenever possible.

In principle the technical problems in data transfer between the two systems should be small.
Further, contacts have been established to the "US - worldwide Chernobyl Data Base", established at the Battelle Pacific Northwest Laboratories.

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